BETT TTEB

Case Study of an Existing Warehouse

A RESEARCH REPORT

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The Buildings Energy Technology Transfer Program (BETT) of EMR has been created to assist building owners, users and practitioners active in the design, construction and operation of buildings in identifying technical obstacles to energy conservation. Through a nationwide network of research agencies and private sector consultants, BETT carries out research and development projects and provides the audiences mentioned above with technical reports, how-to manuals, training manuals, audio-visual aids and data bases to help them overcome these obstacles.

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ABSTRACT

This study was undertaken to document the use and effectiveness of energy conservation technology that has been retrofitted to an existing warehouse building. The projects described and evaluated are fairly typical of the type of energy conservation measures that are being implemented by many energy conscious owners of such buildings.

In this report, each energy conservation project that was undertaken has been described, its financial and technical justification reviewed, and its performance evaluated against the claims originally made. The following projects were evaluated:

- installation of an energy management system for heating equipment
- installation of ceiling fans for better heat distribution
- installation of an air curtain on a large shipping door
- installation of hug strips
- relamping the entire building with more efficient lamps.

RÉSUMÉ

La présente étude vise à documenter l'efficacité des techniques d'économie d'énergie mises en oeuvre lors de la réfection d'un entrepôt existant. Les travaux décrits et évalués sont des exemples passablement typiques de mesures d'économie d'énergie adoptées par le nombreux propriétaires de tels immeubles, sensibilisés aux questions énergétiques.

Le présent rapport décrit chaque projet d'économie d'énergie entrepris, en revoit la justification financière et technique et en évalue le rendement par rapport aux résultats préconisés. Les travaux évalués sont:

- installation d'un système de gestion énergétique pour le matériel de chauffage;
- installation de ventilateurs au plafond pour améliorer la répartition de la chaleur;
- installation d'un rideau d'air chaud à une grande porte d'expédition;
- installation de coupe-vent; et
- remplacement de tous les appareils d'éclairage de l'immeuble par des lampes plus efficaces.

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Appendix 1 - Energy Audit Tabulations

The Buildings Energy Technology Transfer Program (BETT) was initiated by the department of Energy, Mines and Resources (EMR) of the Government of Canada in late 1981. The principal objectives of this program are:

- to identify the potential for energy conservation in both new and existing buildings
- to determine R, D and D requirements and their priority in order to exploit this potential
- to perform and/or expedite the necessary R, D and D
- to effectively transfer the necessary technology to the appropriate individuals, groups or agencies
- to provide technological support to EMR in the development of policy and programs.

The Building Engineering Group (BEG) was selected* by EMR to develop and execute a comprehensive R, D and D program for energy conservation in the warehousing and light industrial building sector. BEG is a semi-autonomous, non-profit agency associated, through the Waterloo Research Institute (WRI), with the University of Waterloo. This multi-disciplinary group attempts to provide a comprehensive range of R and D services to the building industry.

The warehouse and light industrial building sector is particularly important because:

- the square footage of building space encompassed by this category is second only to that of the residential building category
- to date very little R and D, energy-related or otherwise, has been directed towards this building category
- the nature of these buildings, both new and existing, makes them particularly amenable to some degree of energy conservation.

* DSS Number 02SQ.23380-1-6665-4 Serial OSQ81-00137 and Proposal Number WRI 109-01, September 20, 1981

In the initial phase of the R, D and D program developed by BEG, the priorities were to:

- establish a statistical profile of the building category
- develop a comprehensive review of the current state-of-practice
- initiate the development of a portfolio of representative case histories.

Ten related studies are being undertaken in this initial phase. Seven of these studies provide either supporting documentation or input for a comprehensive state-of-practice report.

This report entitled "Case Study of an Existing Warehouse" has been prepared by Richard Hamilton of Moffat Engineering Limited. It is one of two case histories being prepared within this phase of the project. This case history deals with retrofit in a representative building. The active co-operation of Livingston International, particularly Mr. R. Lehman, is gratefully acknowledged.

This report is an early product of what is intended to be a concerted multi-year program of research, development, demonstration, dissemination and evaluation. Feedback with regard to the report or related issues is welcomed and should be directed to the undersigned.

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Moffat Engineering Limited gratefully acknowledges the enthusiastic assistance of Livingston Export Packing and plant engineer, Bob Lehman, in the preparation of this case study.

La présente étude porte sur un entrepôt passablement représentatif. Un certain nombre de réfections visant à améliorer l'efficacité énergétique de l'immeuble ont eu lieu depuis sa construction en 1975.

La superficie totale utilisable est de 22 300 mètres carrés, dont 3 200 mètres carrés sont des bureaux d'administration. Le genre de construction est relativement typique d'entrepôts modernes, à savoir plancher à dalle flottante, mur en blocs de béton et mur rideau métallique, et une toiture multicouches sur charpente métallique. L'immeuble n'a qu'un seul étage. La partie du mur en blocs de béton a une hauteur de 4,9 mtres au-dessus de la dalle de plancher. Le rideau de métal complète le mur 3,1 mtres jusqu'à la hauteur totale de 8,0 mètres au toit.

Le chauffage et l'éclairage représentent la plus grande partie de la charge énergétique et leur consommation constitue la préoccupation principale en matière d'énergie des propriétaires de l'immeubles, comme c'est le cas pour d'autres immeubles semblables. Le coût unitaire moyen de l'énergie a augmenté entre 1977-1978 et 1980-1981 en passant de 2,72 $/GJ à 4,00 $/GJ. L'immeuble est chauffé presque exclusivement au gaz naturel à l'aide de matériel à combustion indirecte ne nécessitant aucun air d'appoint chauffé. Dans la zone d'entrepôt le matériel de chauffage est constitué d'éléments de chauffage à "écoule-ment horizontal". Les bureaux sont chauffés par des appareils de chauffage et de climatisation.

Toute la zone d'entreposage est éclairée par des lampes à halogénures de 400 watts, une amélioration récente remplaçant les lampes à vapeur de mercure. Les bureaux sont écalirés par des tubes fluorescents.

Les autres charges énergétiques importantes sont:

1) la climatisation des bureaux;
2) les chariots élévateurs électriques ou mus au propane;
3) le matériel industriel, y compris un grand compresseur;
4) l'éclairage extérieur; et
5) les ventilateurs installés au plafond.

Cinq réfections visant à améliorer l'efficacité énergétique ont eu lieu depuis la construction de l'immeuble. Ce sont:

- l'installation d'un système de gestion énergétique pour le matériel de chauffage;
- l'installation de ventilateurs au plafond pour améliorer la répartition de la chaleur;
- l'installation d'un rideau d'air chaud à une grande porte d'expédition;
- l'installation de coupe-vent autour de toutes les portes basculantes; et
- le remplacement de tous les appareils d'éclairage de l'immeuble par des lampes émettant plus de lumens par watt.

Parmi tous ces projets, le remplacement des appareils d'éclairage est un succès indiscutable. La consommation énergétique des lampes peut se calculer directement à partir de la puissance nominale. Le nombre des appareils a été réduit d'un tiers et la consommation nominale de chaque appareil est restée inchangée. Il avait été prévu de procéder de toute façon à une réfection importante de l'éclairage. L'installation du matériel à grande efficacité énergétique n'a coûté que 3 500 $ de plus que le remplacement des appareils d'éclairage selon les spécifications initiales. On obtient maintenant le même niveau d'éclairement pour une consommation d'énergie moindre que celle de l'ancien système et les économies annuelles sont de 4 600 $.

Il n'y a pas suffisamment de données pour déterminer si le système de gestion énergétique ou les ventilateurs installés au plafond sont un moyen efficace pour réduire la consommation d'énergie. Ces deux systèmes ont été installés en même temps et des économies d'énergie se situant entre 30 % et 50 % étaient attendues. La consommation de mazout a baissé d'environ 10 % pendant la première année après l'installation. Avant la mise en place du système de gestion énergétique et l'installation des ventilateurs au

plafond, la consommation variait d'environ 10 % d'une année à l'autre. Il semblerait certain que les possibilités d'économies aient été exagérées, notamment si l'on tient compte des données récentes indiquant que l'ouverture fréquente des portes d'expédition contribue de façon très importante à la charge thermique de l'immeuble. Ni l'un ni l'autre des deux systèmes installés n'exercerait une influence sur cette charge thermique. Le vendeur des deux systèmes n'a probablement pas tenu compte de ce facteur.

Il a été constaté que le rideau d'air augmente le confort aux environs d'une porte ouverte, mais il a été impossible de confirmer les mérites de l'installation à titre de mesure d'économie d'énergie.

Finalement, les coupe-vent ont été installés sur les portes basculantes trop récemment pour qu'on puisse déjà constater une réduction dans les factures de chauffage. Toutefois, il serait difficile de nier le mérite de ces installations. Sur une porte échantillon, où le coupe-vent avait été enlevé d'un côté, on constatait un fort courant d'air froid qui pénétrait dans l'immeuble du haut jusqu'en bas de la porte. Du côté équipé d'un coupe-vent, aucune infiltration n'a pu être discernée. Une grande partie du matériel utilisé comme coupe-vent consistait en anciennes courroies d'entraînement. C'est un excellent exemple d'une mesure d'économie d'énergie qui nécessite plus d'ingéniosité que de fonds.

La société Livingston Export Packing a eu un succès variable avec les projets d'économie d'énergie entrepris. Des données recueillies à l'avenir établiront peut-être si le système de gestion énergétique et les ventilateurs installés au plafond contribuent réellement de façon sensible aux économies d'énergie. Les propriétaires ou exploitants d'entrepôts et d'autres immeubles d'industrie légère feraient bien d'entreprendre une analyse soignée des charges énergétiques actuelles avant de décider d'investir dans ces mesures. Il faut faire preuve de scepticisme à l'égard de prétentions non justifiées ainsi que de prétentions fondées sur des économies obtenues dans des circonstances très différentes.

Il se peut que la mesure la plus importante d'économie d'énergie serait de réglementer la fréquence et la durée d'ouverture des portes. Il conveint d'étudier davantage cet aspect de l'exploitation des entrepôts et des immeubles d'industrie légère.

This is one of a series of case studies being compiled in order to assemble a comprehensive dossier on the state of practice for energy conservation techniques in warehouse and light industrial buildings in Canada. The objective in performing these case studies is to document the use of technologies whose development and implementation is intended to conserve energy. We are interested in devices and procedures installed in buildings or applied to building operations which are claimed to reduce energy consumption from a previous or normal level. This applies to new buildings, where the devices or procedures would be an exceptional part of a standard plan, or to existing buildings, where the device would be retrofitted or the procedure implemented after some period of operation.

Livingston International is a group of independently operating divisions and subsidiaries providing services to support the export and distribution industries. Corporate activities include specialized export packing and container manufacturing, customs brokerage and freight forwarding, pool car and distribution services, and public warehousing. Livingston Export Packing is an operating division located in Tillsonburg, Ontario. The subject of this case study is a building belonging to Livingston Export Packing. Activities in this building include export packing, freight forwarding and public warehousing.

We have attempted, in this study, to identify all the bona fide energy conservation measures taken in this building, the technical and financial rationale for their implementation and the derived benefits.

In most cases, the technical and financial rationale was easy to obtain as it had been well documented for project approval. On the other hand, evidence of benefits was much more difficult to obtain. Our

experience in the energy management field has been that most buildings have metering only at the primary distribution level for each energy source. There is rarely any ongoing metering of the energy consumption of individual loads. This building is not an exception to that rule. It was necessary to isolate trends from the gross consumption records and speculate as to their cause. In some respects, this exercise might be likened to finding a hypothetical needle in an actual hay-stack. As many variables as possible- production schedules, building service operation schedules, etc.-have to be isolated and their effect deduced from the gross energy consumption. Based on these factors, a load breakdown of the gross consumption figures is arrived at and energy savings can be determined. Operating experience was documented mainly from interviews of plant personnel.

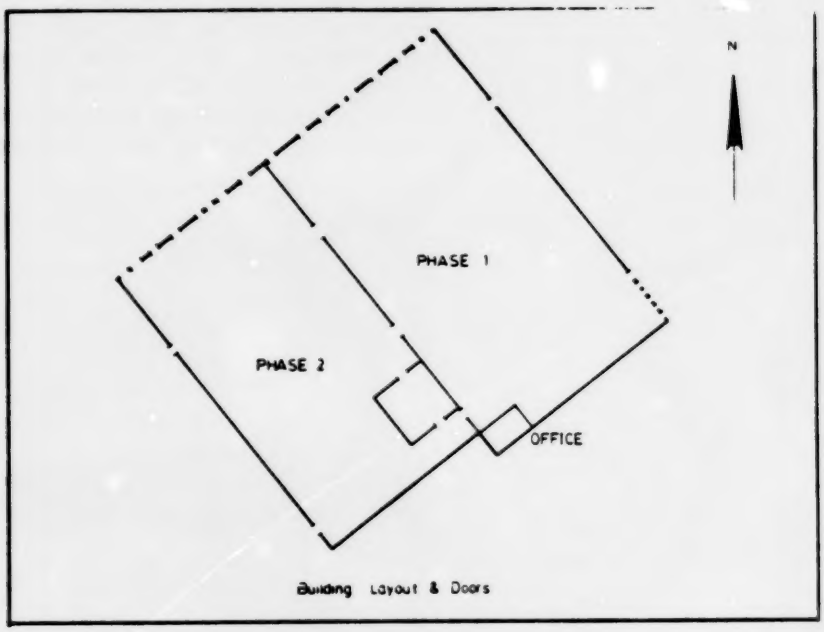
Our objective in this case study is to identify and document the performance of an existing warehouse building that incorporates retrofit/renovation measures for energy conservation. The principal objective is to detail, analyze and assess each of the retrofit measures that were taken to reduce energy consumption.

This warehouse facility is located near Tillsonburg, Ontario, on Highway 3 near the intersection with the main road into Tillsonburg. The front wall is oriented parallel to a bearing of N52 deg E, as is the highway. It is a one-storey building of steel frame construction and was built in two stages in 1975. The building is a warehouse used for the receiving, storage and shipping of automobile parts.

Phase 1 of the building, the first erected, is 85 metres wide by 148 metres long. Phase 2 is adjacent to phase 1 and is 73 metres wide by 137 metres long. The two phases of the building are separated by an internal concrete-block masonry wall which supports the roof at mid-span. Despite the wall, building services to the two phases are not segregated.

One area which is segregated (separate heating and lighting, plus air-conditioning not found in the warehouse area) is a 12-metre by 18-metre office area located in the south-most corner of phase 1. This area is surrounded by a concrete-block and load-bearing wall.

The building's total area is roughly 22,600 square metres of which only about 216 square metres are devoted to office space. The remainder, almost



Building Layout & Doors

22,400 square metres, is devoted to warehousing operations.

The floor of the building is concrete slab, 100 mm thick. Along the length of both the south-west wall and the north-east wall, indoor rail sidings are trenched, with the car floor level at grade. The rail bed is gravel.

Enclosure of Structure and Building Fabric

The exterior walls are all non-load bearing. The north-east and north-west walls and most of the south-east wall are of similar construction. This consists of 200 mm concrete block to a height of 3.1 metres and insulated steel cladding for the remaining 4.9 metre height of the building. The cladding is insulated with 38 mm of vinyl-backed

fiberglass batt. The south-west wall is constructed of 300 mm concrete block from floor to ceiling, unfinished.

The office area has 200 mm concrete block from floor to ceiling. The exterior is faced with brick to a height of 3.1 metres, with pre-finished aluminum siding for the remaining 4.9 metres. The siding and block sections are separated by 38 mm fiberglass batts.

The flat roof is supported on open web steel joists. The built up roof membrane rests on 25 mm of particle board and is covered with approximately 8 mm of gravel.

Thirty-five doors breach the warehouse section's envelope. The type, size and location of these doors are shown in the following table:

Doors in Plant 22

Type	Size	N-E	S-E	S-W	N-W	Total # of type
Rail Doors 16 Ga Steel Single Wall Rolling Steel	5x9m	-	-	-	2	2
Shipping Doors	4x6m	5	-	-	4	9
Plywood Panel	4x8m	-	-	2	3	5
Overhead	6x6m	-	-	-	5	5
	6x8m	2	-	-	2	4
Man Doors Plywood	1x2m	2	4	2	2	10
Total # per wall		9	4	4	18	35

Of the shipping doors, five 4x6m doors on the north-east wall near the east corner of the building are equipped with dock seals. There are three

shipping-type doors which appear to get far more use than any other due to the traffic in lift trucks through them. These are two 4x8m doors located on the south-west wall near the west corner and on the north-west wall near the centre of the building (at the internal wall separating phase 1 and 2) as well as a 6x8m door near the docks on the north-east wall.

The only windows in the building, other than a small number installed in some doors, are located in the office area. These are double glazed in hermetically sealed extruded aluminum frames. They are fixed in place and do not open.

Service Systems

Building heating is almost exclusively natural gas. There are several auxiliary electric baseboard heaters in the office area.

In the warehouse area, heating is supplied by 43 indirect-fired natural gas unit heaters. These devices are rated at 250,000 BTU heat input to the building each, for a total installed capacity of 10.75 MM BTU/h. They are of the horizontal flow type and have an efficiency rating of about 72% under normal operating conditions. Combustion air is drawn from within the building, with exhaust gases being vented outside after passing through the heat exchanger. The unit heaters are arranged around the periphery of the building. The heated air is directed at the wall, but is offset by about 45 degrees. This evidently promotes circulation of building air.

There are eight heating zones within the warehouse section, four in each phase. An "energy management system" is used to transfer control of each zone's heating equipment from normal to set-back thermostats during dark hours. The energy management system is essentially a microprocessor-based timer with either control loops or points. Standard 24 V output signals drive relays which switch the thermostats. The controller can be programmed to give each zone its own operating schedule.

One hundred and nineteen ceiling fans are used to combat warm air stratification. These have a continuously variable speed, controlled thermostatically. As the ceiling temperature rises within a zone, the fan speed is increased to destratify the air. Each of these fans is equipped with a thermodisc heat fuse which will cut the power to fan in the event of very high temperatures. This is to prevent the inadvertent fanning of a fire.

Heating/cooling plant for the office is in the form of three packaged, roof-top heating/cooling units. Cooling is by the DX process and heating by indirect natural gas fired equipment incorporated into the unit. All three units have provision for fresh or recirculating air, the latter being the setting in use. In total, 25 tonnes of cooling capacity are installed and 240,000 BTU/h of heating capacity.

Lighting in the warehouse area is now provided by 420 400W metal-halide lamps mounted at about a 7m height on approximately 7.5m centres. Light levels in the plant are generally in excess of 30 foot-candles. All lighting is manually switched. The lighting has been zoned to allow the lights in major corridors to be turned on during dark hours, but the bulk of the lights to be turned off.

There is little need for hot water heating in this building. The two standard household-type electric hot water heaters are sufficient. Hot water piping is insulated.

The major "process" equipment in the building is in the form of lift trucks, of which there are battery-powered and propane-powered. The propane-powered lift trucks cause pollution in the form of carbon monoxide emissions. This problem has been addressed by natural convection ventilators, originally built into the roof as a fire protection measure, and by careful attention to the tuning of the trucks' engines.

A second process is the preparation of parts for overseas shipment. A 20 P compressor supplies compressed air for the required oil-spraying. This air is also used for pneumatic hammers used in crate fabrication.

Finally, there is a small complement of wood-working equipment for crate manufacture, although most of this work is done offsite.

In analysing the effectiveness of each of the five energy conservation measures, we have attempted to account for the monthly energy consumption, gas and electric, on a month-by-month basis over a period before and after project implementation. The results of this audit are shown in Appendix 1. Each of the audit print-outs, gas and electric, represents a plausible scenario compiled to explain the gross billed consumption. These figures were arrived at by considering production schedules, equipment operating schedules, connected loads and equipment efficiencies. The auditing technique is computer-based, with the scenario being continuously refined to resolve discrepancies arising from each preceding pass and to accommodate new information derived from the discrepancies.

Figures 1 and 2 graphically show the energy usage breakdowns derived from the audit.

Figure 1

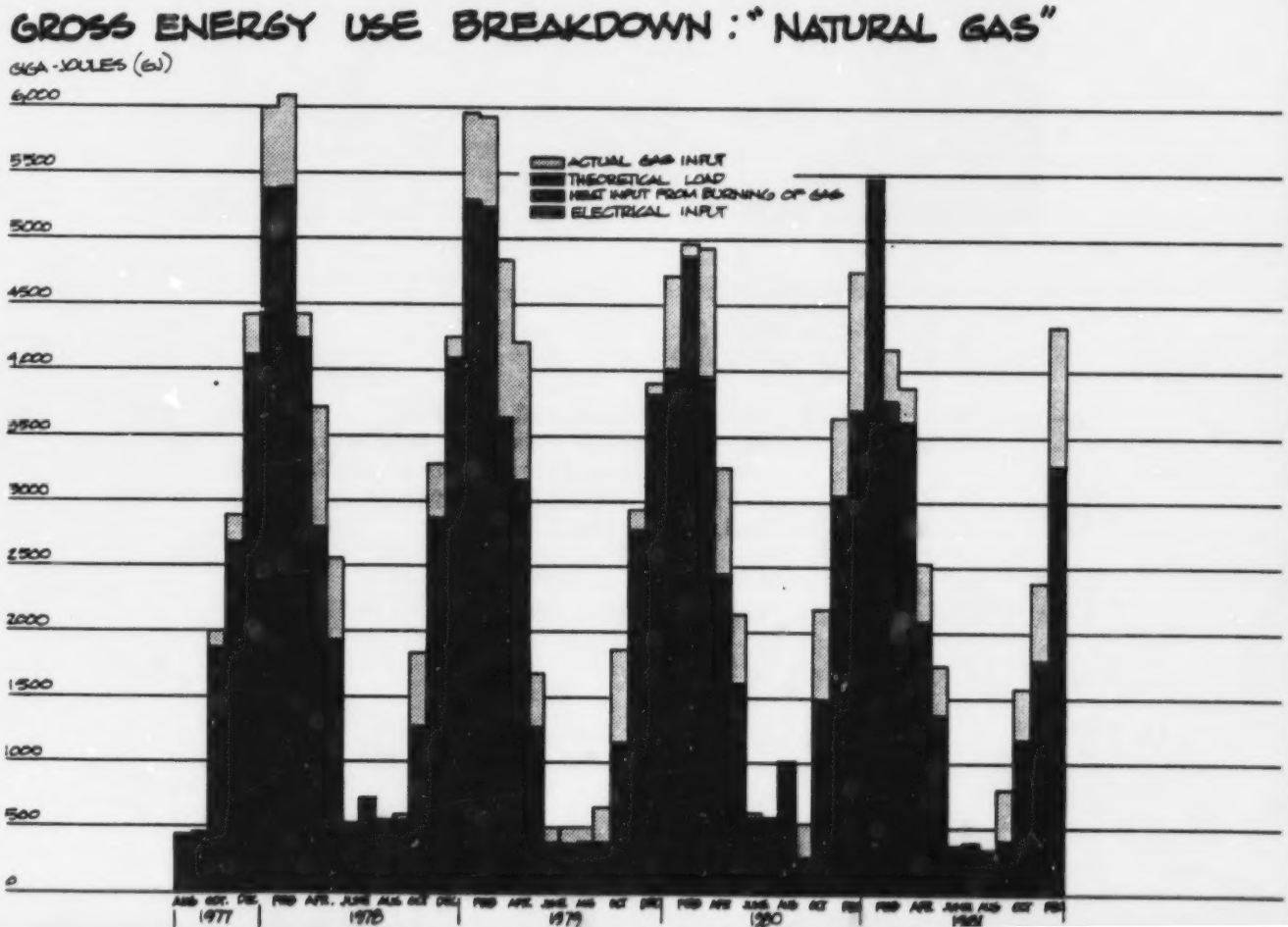
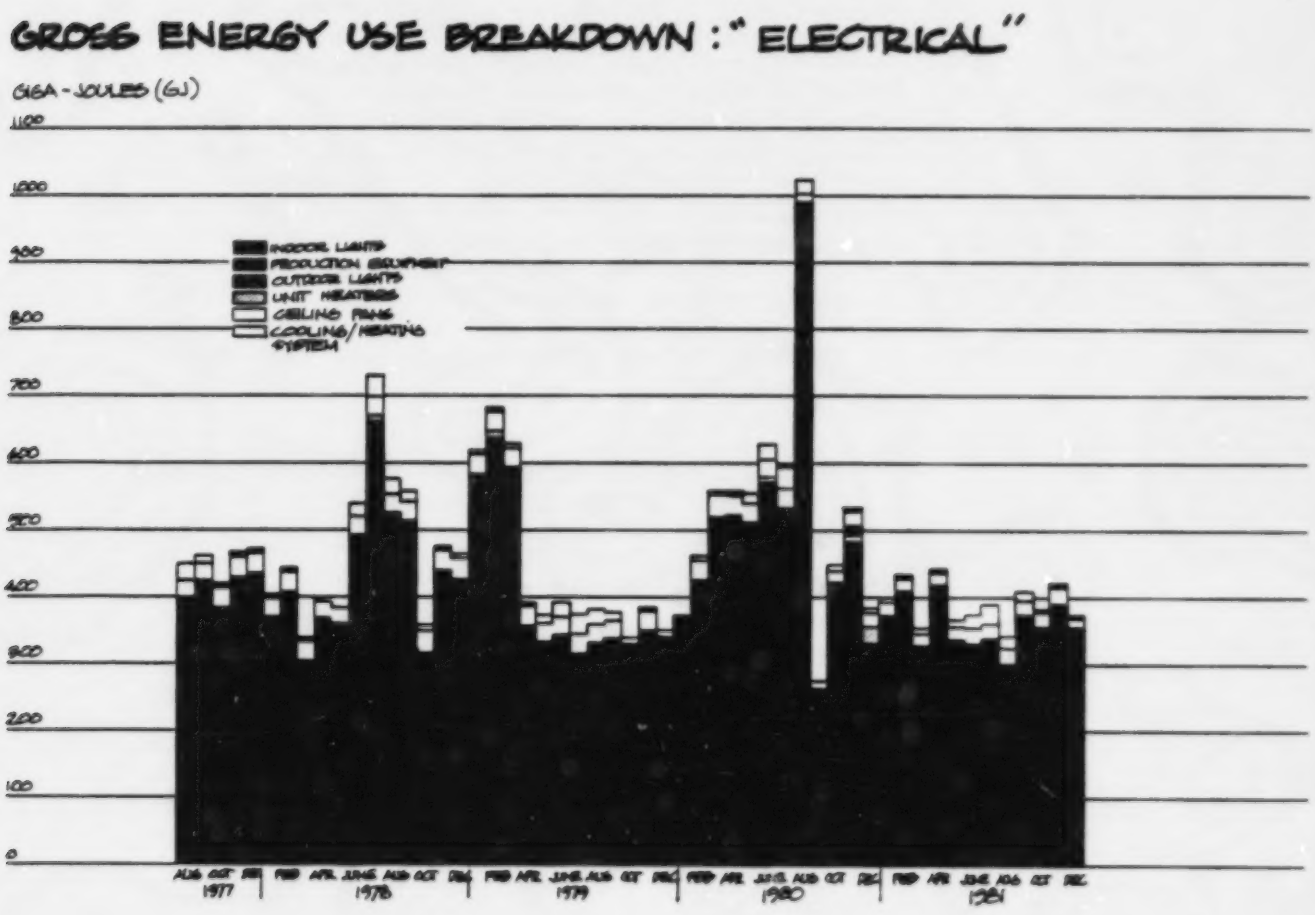


Figure 2



Tables 4.1 to 4.6 show the tabulation of some illustrative statistics extracted from the audit data. These figures are discussed further in the following sections.

TABLE 4.1

TOTAL ENERGY CONSUMPTION
ANNUAL

Fiscal Year	Total Energy Consumed [GJ]	Total Cost of Energy [$]	Average Unit Cost of Energy [$/GJ]
1977/78	37,441	101,725	2.72
1978/79	38,085	115,698	3.04
1979/80	33,243	114,660	3.45
1980/81	32,258	129,143	4.00

TABLE 4.2

GAS CONSUMPTION SUMMARY
ANNUAL

Fiscal Year	Total Gas Consumption m^3 (MCF)	Total Gas Energy GJ (MMBTU)	Total Cost of Gas $	Average Unit Cost of Gas $/100$m^3$ ($/MCF)	Average Unit Cost of Gas Energy $/GJ ($/MMBTU)
1977/78	856,976 (30,260)	31,919 (30,260)	66,572	7.77 (2.20)	2.09 (2.20)
1978/79	864,212 (30,516)	32,188 (30,516)	76,356	8.84 (2.50)	2.37 (2.50)
1979/80	743,485 (26,253)	27,692 (26,253)	70,401	9.47 (2.68)	2.54 (2.68)
1980/81	720,619 (25,446)	26,840 (25,446)	83,246	11.55 (3.27)	3.10 (3.27)

TABLE 4.3

ELECTRICAL CONSUMPTION SUMMARY
ANNUAL

Fiscal Year	Total Electrical Consumption	Total Elect. Energy	Total Cost of Elect.	Average Unit Cost of Elect.	Average Unit Cost of Elect. Energy
	MWh	GJ	$	cents/ kWh	$/GJ
1977/78	1,534	5,522	35,153	2.29	6.37
1978/79	1,638	5,897	39,342	2.40	6.67
1979/80	1,542	5,551	44,259	2.87	7.97
1980/81	1,505	5,418	45,898	3.05	8.47

TABLE 4.4

HEAT INPUT AND DEGREE-DAYS
ANNUAL

Fiscal Year	Degree-Days From 18.3°C	Heat Input (Gas & Electric)	Heat Input Normalized To Degree-Days
	[°C-d]	[GJ]	[GJ/°C-d]
1977/78	4,364	35,832	8.21
1978/79	4,131	36,959	8.95
1979/80	4,031	31,678	7.86
1980/81	4,082	30,784	7.54

TABLE 4.5

KEY ENERGY DENSITIES
GJ/m^2
ANNUAL

Fiscal Year	1977/78	1978/79	1979/80	1980/81	Average
Energy Consumer					
Warehousing Lighting	0.178	0.201	0.203	0.132	0.179
Warehouse Heating & Air Handling	1.445	1.457	1.256	1.220	1.345
Warehouse Production Equipment	0.048	0.039	0.023	0.086	0.049
All Energy Consumed	1.679	1.708	1.491	1.447	1.581

TABLE 4.6

PERCENTAGES OF TOTAL
ENERGY CONSUMED
BY INDIVIDUAL LOADS

AVERAGES

Warehouse Production Equipment.....3.1%

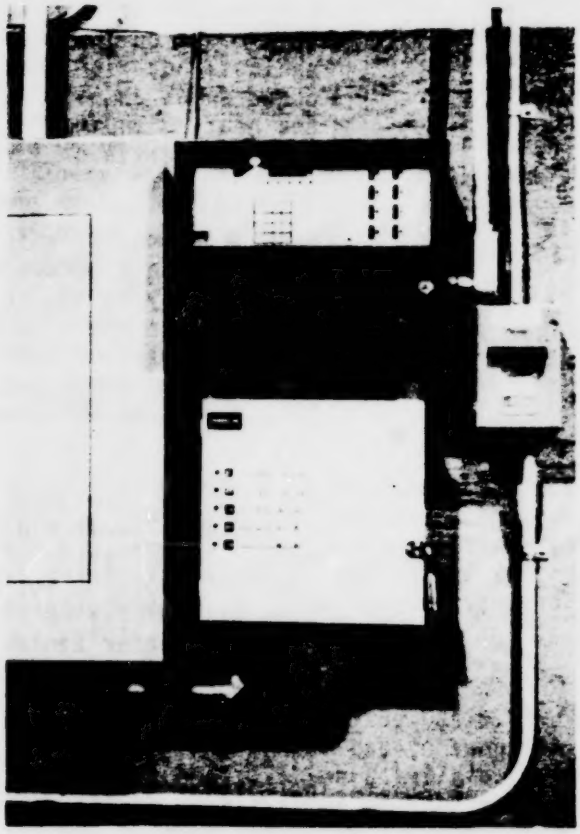
Warehouse Lighting.....11.3%

Warehouse Heating & Air Handling.....85.1%

Miscellaneous Including Outdoor Lights and Office Heating & Cooling..... 0.5%

100.0%

Prior to December 1980, the entire warehouse area of the building was operated at a single temperature set-point value, twenty-four hours a day. This value was 21°C. Groups of three unit heaters each had their own thermostat. In November 1980, a 12-point microprocessor-based, programmable time controller was installed to take advantage of heating set-back in the winter. The building was split into four zones, each with individual thermostat control for the included unit heaters.



This system includes set-back thermostats, in each of the four zones, which are set to the desired set-back temperature of 10°C. During hours when the building is not occupied, the time controller switches control of heating equipment from the normal thermostats to the set-back thermostats.

5.1 Technical Review

With only one or two shifts a day, five days a week, this building's occupancy ratio is quite low. The goods housed can easily tolerate a lower temperature than 21°C. It was reasoned that considerable energy savings could be achieved by heating the building to the normal 21°C only during the normally occupied hours; a cooler building during unoccupied hours would lose less heat and, therefore, waste less energy. A set-back temperature of 10°C was thought to be reasonable. This would be low enough to effect considerable savings, but high enough to guard against such occurrences as pipe freeze-up or the inability of the heating equipment to overcome the building's thermal inertia on a return to full heating.

Manual thermostat adjustment was regarded as too unreliable because different set-points could accidentally be set in different zones causing the equipment in one zone or other to fight each other. There had already been some problems with unauthorized tampering with thermostats. As well, this procedure would be time consuming.

The programmable time controller was chosen because it would allow flexibility for future control points, flexibility of scheduling, and the circuitry involved would be fully compatible with the long-term plan of having all of Livingston's Tillsonburg buildings under central computer control. Essentially, this device is simply a micro-processor clock. An instruction register for each of the twelve control points is scanned once every minute. If an instruction is stored there, for that particular time, it is implemented by changing the state of the controller's output for that control point. The output of each of the four control points used in this application drives a relay whose position determines whether the normal thermostat or the setback thermostat, for the controlled zone, will be used to control the zone's heating equipment.

There have been no particular technical problems with this installation. It was found that a manual override, separate from the controller itself, had to be provided. This was because unexpected events occasionally take place where full heating is required during a scheduled set-back period. The controller and override were separated to prevent unqualified personnel from accidentally altering the basic control sequence. The override is timed-out.

One minor problem occurred during a scheduled Christmas shut-down. The controller had been set to "HOLIDAY" mode. Its normal schedule had been "ON" at 6:00 a.m. daily and "OFF" at 12:01 a.m. daily. Unbeknownst to the staff was the fact that "HOLIDAY" mode was, in the machine's logic, "REVERT TO LAST COMMAND OF DAY". That was actually the 6:00 a.m. "ON". Therefore, for much of the holiday, the heating system was operating at full load. This situation was discovered and corrected. The timer is now programmed for "ON" at 6:00 a.m. and "OFF" at 11:59 p.m. Otherwise, the controller has operated as expected.

5.2 Economic Review

The cost of the project in December 1980 was $11,570.00. This included the four required set-back thermostats, one for each zone, the timer controller itself and installation of the entire system. The installation was done by the contractor who supplied the equipment.

The project was justified on the basis of a potential saving of 20% of the annual gas consumption for heating. For the fiscal years 1977/78, 1978/79 and 1979/80, before installation of the set-back system, the gas consumption was 856,975 cubic metres, 864,211 cubic metres and 743,486 cubic metres respectively. Corrected for annual degree-days (^{o}C) and for the fact that an annually varying amount of building heat is derived from the operation of interior electrical equipment, those figures are 220

cubic metres per degree-day, 240 cubic metres per degree-day, and 211 cubic metres per degree-day, thus exhibiting some variation. The average heat required was equivalent to 224 cubic metres of gas for each degree-day of the heating season. In 1980/81, the first year of operation of the set-back system, the building used 202 cubic metres of gas for each heating degree-day.

This reduction, from the previous three years' average, cannot reliably be attributed to the energy management system. The actual amount is about 10% down from the average, but there is that much variation in the figures from which the average was calculated. The only way to establish whether this change is significant is to determine whether all of the other input factors remained the same.

We were especially concerned about production levels and how they influenced such parameters as periods of doors being left open. These factors will influence the overall heat load and could well have masked the effectiveness of the energy management system, or its lack of effectiveness. Unfortunately, the information required is not available in sufficient detail (it simply has not been monitored that closely) to decide whether the change is significant.

Had the projected energy saving occurred, or were it possible to demonstrate that it had occurred, we would be looking at a monetary saving of about $22,000., for 1980/81 fiscal year, based on the then current gas price of about 12.14 cents per cubic metre in the major consumption price tier (M-2 rate card). This would have paid back the installation within the year, an excellent pay-back.

5.3 Overall Review

As we have said, there is little demonstrable improvement in the energy efficiency of this building and this cannot be credited to the energy management system with certainty. This is not to say that it has not worked at all or that it will not in future. In fact, based on our own experience this seems highly unlikely. There are several things which should be considered. This was the first season of operation for the system, and some fine tuning might be required to get the projected performance.

The problems during the Christmas holiday are a good example of this need for fine-tuning. Because of an unknown system idiosyncrasy, much gas was wasted over that period. Moreover, the statistics could lie in other ways. Perhaps 1980/81 was a year during which the doors had to be kept open for a longer period of time due to some particular production requirement. We do not have the data to evaluate this possibility. More time and better data will be required to evaluate the performance of this system.

At about the same time as the temperature set-back system was installed, 119 ceiling fans were installed throughout the building. These fans were installed to combat temperature stratification and the attendant heat loss through the roof. They are equipped with variable speed drives, the speed of rotation being governed by zone thermostats. They are also equipped with "thermodisc" heat detection devices to automatically shut them off in the event of a fire below. This last item was at the request of the plant engineer and is now included as a standard feature of the fan supplier's product.

6.1 Technical Review

Prior to installation of the ceiling fans a very noticeable temperature stratification occurred in the warehouse. Typically, the temperature of the air at ceiling level was about 32°C whereas at floor level it was about 10°C. It was reasoned that this caused losses in two ways. First, as the occupants worked in the lower half of that stratified air, the building would generally have to be heated a greater amount than necessary to maintain their comfort. Second, the heat reservoir at the ceiling would cause a much higher than necessary temperature gradient across the roof to outside. Both of these factors would cause a large amount of wasted heat. Ceiling fans would eliminate that waste and help recover some of the heat gain from the lights during the heating season.

The manufacturers estimated that roughly 30% to 40% of the annual gas consumption for heating could be eliminated by the installation of fans. This estimate was produced by their computer analysis which took into account the existing temperature profile and the building's construction.

On installation, the fans immediately eliminated the stratification effect. A before turn-on test verified the floor and roof temperatures as $10^{o}C$ and $32^{o}C$ respectively. As soon as the fans were installed and turned on, the temperature gradient was eliminated and an even $21^{o}C$ was achieved. There were a couple of untoward effects though.

First, it was found that the more rapidly circulating air tended to entrain particles of oil from the sprayers used to coat export parts. The oil was then deposited on the heat exchange surfaces of the unit heaters which happened not to be fired at the time. When heat was called for from such a unit heater, a jet of blue smoke was the first evidence of its operation. This caused something of

a pollution problem. The solution was to adjust the sprayer nozzles to produce a courser mist. This did not effect the process quality, but solved the pollution problem by eliminating the entrained oil.

The second problem was the unwanted de-stratification of noxious gas. Several propane-fired lift trucks are used in this plant. These, of course, exhaust pollutants, the most dangerous of which is carbon monoxide. Carbon monoxide is lighter than air at the same temperature and pressure, and it tends to collect at the ceiling of an enclosed space. No sooner had the ceiling fans been turned on than excess carbon monoxide concentrations at work level were detected. This problem had not been anticipated, but was easily cured. Fused link smoke ventilators, installed in the building at the time of construction, were selectively opened to alleviate the problem until a final solution could be implemented. This was the implementation of a very careful tune-up program for the lift trucks (This was done throughout the company). These tune-ups not only eliminated the pollution problem, but they resulted in ongoing truck fuel savings as well. The ventilators were then closed again.

6.2 Economic Review

The cost of this project was $26,900.00 in October, 1980. This included the supply and installation of all fans as well as the supply and installation of their control system. The job was handled on a turn-key basis by the manufacturer.

The project was justified on the basis of the manufacturer's claim of a 30% to 40% reduction in the gas consumption over a heating season. We find that claim somewhat excessive, but we would expect the project to show a good return based on our own experience. Given a 30% to 40% reduction of gas

consumption, a saving of $33,000 - $40,000 could be expected for the year 1980/81, but, not realized. There is, again, no ready explanation available for this discrepancy between actual performance and predicted performance. As far as plant staff know, the system was operated in accordance with instructions and did produce a perceptible result in destratifying the air. The system either has indeed not lived up to expectation in reducing energy consumption, or its performance is being masked by some other unknown factor or factors.

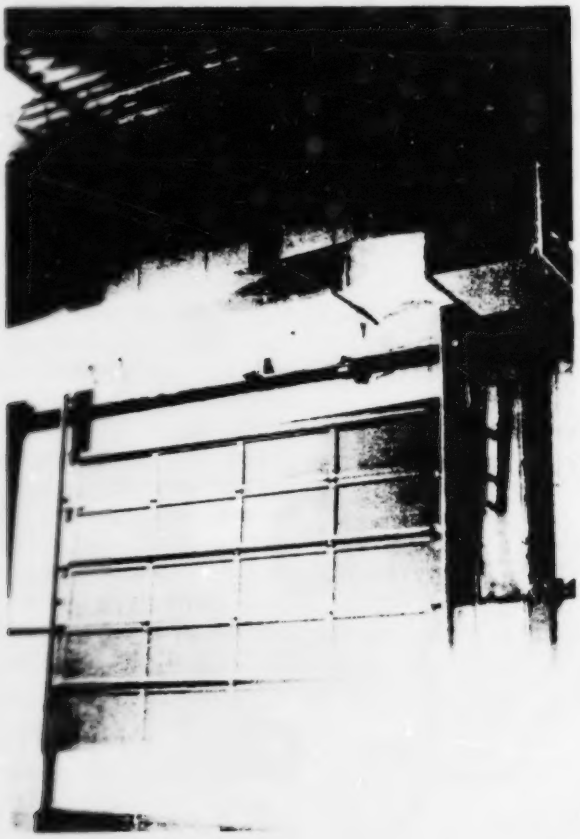
An additional operating cost was incurred: that for the electric power required to run the fans. We have estimated that the annual consumption of these fans, running twenty-four hours a day, seven days a week, is of the order 338 GJ annually. This additional energy consumption is partly offset since the ceiling fans allow the unit heater fans to be shut off entirely during the summer months and whenever the burner is off during winter months, for a saving of about 126 GJ annually. This leaves a net incremental electrical energy increase of 212 GJ annually for operation of the ceiling fans. At 1980/81 rates, the cost of that electrical power is about $1,800. This must be deducted from any potential savings in gas consumption, but would be an insignificant amount if the predicted gas savings had been achieved.

6.3 Overall Review

This project, like the night heating set-back system has not shown evidence of any dramatic improvement in the gas consumption figures. We find that fact difficult to reconcile with our own experience in these matters which has been that the savings are quite easy to establish and are substantial (though we are not as optimistic as the manufacturer of the fans). We cannot determine with certainty any particular reason for the project's apparent failure, but again we suspect it to be due to some unknown factor or factors related to production and heating load misassessment.

7. INSTALLATION OF AN AIR CURTAIN ON A LARGE SHIPPING DOOR

The warehouse under study has a large number of overhead doors. Shipping and receiving of goods is the major activity carried out in this building. Thus these doors are frequently wide open, and the resulting energy loss is a matter of concern. Mainly as an experiment, an air-curtain was installed on one door to evaluate the usefulness of this type of device. This air-curtain was designed and installed by a local contractor in November 1980.



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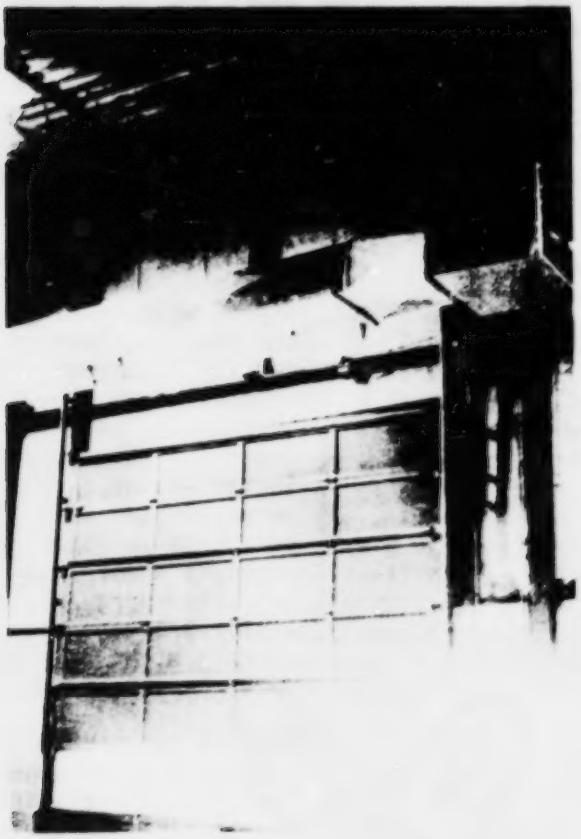


7.1 Technical Review

The project was justified largely on the grounds of its low cost (only one of numerous doors in the building was so equipped) and the fact that it was done on a trial basis.

Although operating statistics were impossible to obtain, we did observe the operation of this unit. The curtain air is drawn from just below the ceiling above the upper level of the door. The plenum extends the width of the door and has fixed nozzle vanes. Because these nozzles are fixed, the jet itself is unidirectional. The most advanced of these systems have differential pressure gauges to control the jet direction according to the differential pressure between inside and outside.

On the day that the operation of the system was observed, a light snow was falling. There was a direct wind bearing on the face of the building where the door was located. With the air-curtain turned off and the door open, the draft through the door was sufficient to blow snow 15 or 18 metres into the building. There was a definite in-rush of cold air. Under the same conditions, but with the air-curtain turned on, no snow at all entered the building. Surprisingly, very little of the warm air in the jet seemed to be escaping. The jet and the outside pressure seemed very well balanced. In an area such as Tillsonburg, where the prevailing winds during the winter are generally constant, this type of air-curtain might be, technically, quite appropriate.

Now, as has been discussed in sections 5 and 6, we suspect that a larger portion of the building heat load than was originally surmised might be attributable to the infiltration through open doors. We look upon this as a possible explanation for the lack of tangible results from the energy management system and the ceiling fans. If these air curtains are, in fact, effective, then this might offer a solution to this problem. We should add that these devices certainly increase workers' comfort around open doors.

7.2 Economic Review

The cost of this project was $1800, installed.

Obviously, a single air curtain, installed on only one of twenty-four doors, will not have a measurable impact on the gross heating energy required. We have not attempted to isolate its effects. Nor are energy savings directly measurable. But there is one way of assessing the return on investment. At $1800. each, the cost for outfitting all doors with these air curtains would be roughly $43,200. To obtain a three year pay-back, the savings in energy costs would have to be of the order of $14,400. annually. At 1980/81 prices this would be about 125,000 m^3 or about 15% of annual consumption. If they are always as effective as they seemed to be the day of our observation, this might not be an unlikely return. In fact, given the evidence that open doors contribute substantially to the heat loss in this building, air-curtains merit further investigation.

7.3 Overall Review

Some form of barrier to infiltration at open doors would almost certainly do good in terms of overall energy savings. The question is: at what cost to give a good return? One factor which does not favour air curtains is that they consume electrical energy themselves in blocking infiltration. Perhaps a passive barrier such as strip curtains would be as effective with less initial and ongoing costs. The whole issue certainly deserves further study in light of our suspicions as to heat loss through open doors.

Over the calendar year 1981, a program to install "hug-strips" on each overhead door in the building was completed. These hug-strips are simply rubberized slats which are bolted or fixed along one edge to the door jamb, with the other edge pushed against the door. Their purpose is to reduce the amount of cold air passing through the cracks around the side of the door.

8.1 Technical Review

When overhead doors are first installed, the sealing of the edges, between door panel and jamb, is quite good due to the close tolerances of the track upon which the door panels ride. Over a period of time, this track tends to shift and bend so that the crack between door and door jamb gets wider. This is normal wear and tear and, although it does not really affect the door's opening and closing, it certainly does allow a vastly increased rate of outside air infiltration. This infiltration, of course, is a form of energy waste.

Although the tracks can be re-adjusted, it was reasoned that a better way to reduce the attendant energy losses would be to install hug-strips. This would avoid the periodic need for difficult re-adjustment of the track on each door in the building.

Two types of hug-strips have been experimented with. One is a "home made" type, with worn-out machine drive belts used as the flexible belt. These are screwed to a length of angle iron which is then tack-welded to the steel door jamb.

The other is a commercially available brand, made of a specially treated rubber compound. This is simply sandwiched to the steel door jamb by a thin cover-plate which is screwed in.

Either version was found to be equally effective in reducing the rate of infiltration, and the reduction was substantial. Evidence of that was found during one site visit when a door whose hug-stripping had been removed on one side was observed. On the side of the door with no stripping, a cold draft rushed in. This could be felt along that entire edge of the door. It was pointed out that the track misalignment on this particular case was less than usual. We estimated that the draft velocity was about 2.54 m/s.

The crack length was about 2.44 m and the crack width about 1.3 cm. Roughly, that would give an air infiltration rate of 0.08 m^3/s for that crack alone. On the other side of the door, where the stripping was intact, the air infiltration was barely discernible. Hug strips are effective.

The commercial hug-stripping has been found to be more durable than the homemade. It retains its flex in cold weather and does not fray as easily, but it is also more expensive.

8.2 Economic Review

Hug strips cost very little to implement. The plant staff estimates that the maximum cost, using the commercial hug stripping, would be $13.00 per metre installed. There is a great deal of room for ingenuity though, which can reduce the costs substantially. The worn drive belts used on the home-made hugstrips were considered to be scrap before they were recycled into hug-strips.

As to savings involved, it has been pointed out that these strips reduced the outside air infiltration around a door to practically indiscernible amounts. Such infiltration represent a substantial portion of the heating load in this type of building. It is very difficult to predict this proportion, but it is sure to be high. Using the observed door as an example, the infiltration from the open crack was about 0.08 m^3/s. If the winds are fairly constant this rate of infiltration will also be constant. An average heating season in Tillsonburg is about 4,170 degree-days long. On that basis, the losses to infiltration from that single crack will be 35 GJ annually.

At the efficiency with which heat is provided, 75%, infiltration would consume 1,250 m^3 of gas during a typical heating season, at a cost of roughly $150. At $13.00 per metre installed, it would cost about $32.00 to seal the crack with hug-stripping. The theoretical payback is thus reached in about 0.2 years.

8.3 Overall Review

We think that this project is typical of a number of like measures which can be taken without a considerable amount of analysis and deliberation. The costs are small or negligible; the benefits are obvious; and implementation can be arranged around the existing operation. They require no special knowledge, other than an awareness of the implications of leaving them unattended. It is too early to detect evidence of these measures in the gross consumption. The project has just recently been completed. We are, nevertheless, confident that these measures will have the excellent payback implied in this analysis.

The building was originally lamped with 400 W mercury vapour luminaires. The light level provided by these luminaires was an average 20-30 foot-candles at work level. During October of 1980 a relamping program was embarked upon which saw the relamping of the entire building with one-third fewer fixtures of the same rated wattage, in a more efficient metal halide lamp. These lamps have a higher lumen output per watt.

9.1 Technical Review

Frequently, relamping of a building to achieve energy savings is not as easy a task as it might seem. Zoning problems often arise. The new lamps, spread more thinly than the old, create light distribution problems. Extensive rewiring is sometimes necessary. As it turned out, this particular building did not have those difficulties because it is a basic rectangle with few complicating factors. All of the existing circuits could be utilized with only minor changes; only the spacing between lamps was altered. The desired effect was uniform lighting throughout, as had previously been the case.

The original 400 W mercury vapour lamps were, in many cases, approaching the end of their useful lives. One disadvantage of these lamps is that they continue to glow while not putting out much useful light. Because they are glowing they do not get changed, but the light level falls to unacceptable levels. Plant staff may not discern the difference (they become accustomed to it), but productivity usually falls. This was the state that most of the lamps were in prior to relamping. When it became evident that something would have to be done, it was decided to look into more efficient equipment.

A more modern metal-halide lamp was available to replace the existing mercury-vapour lamps. It happened that the same fixtures could be used. Only the ballast (this only in some cases - many of the ballasts were reusable) and the lamp itself would need to be replaced. It was further determined that only 420 metal halide lamps would be required to replace the existing 645 mercury-vapours and still give the same (as originally installed) light levels. As the replacements were each 400 W, the same wattage as the originals, the saving in energy would be quite considerable. Finally, those mercury-vapour fixtures that were still in acceptable condition would be reused elsewhere in the company's facilities.

This project has been implemented, and there have been no particular problems with the new lighting system. In fact, the light levels have turned out to be better than expected. The average light level, at working height, is now fifty to sixty foot-candles compared to the expected thirty or forty foot-candles. Just prior to relamping, the light level was only twenty foot-candles.

9.2 Economic Review

The entire cost of relamping came to $18,448. This included washing all of the mercury-vapour fixtures, removing those that were not required, relocating a number of the remaining ones to wider centres and installation of the required lamps and ballasts themselves. The cost of simply re-lamping the fixtures with replacement mercury-vapour lamps, a measure which would have been taken anyway, would have been $14,943. The incremental cost of the new system was thus $3,505.

The full-load draw of the original 645 mercury-vapour lamps was about 284 kW. The full-load draw of the new fixtures would be about 185 kW. The difference is about 99 kW. The energy saved in a year, as a result of this decrease in consumption, would be about 1,020 GJ, worth about $7,900. This quantity is based on single-shift operation and would increase with two-shift operation.

On the other hand, this reduction in lighting energy will mean an increase in the heating requirements for the building during the heating season. In fiscal year 1980/81, the useful heat input of the lights (new system) was about 1,670 GJ. With the original system, that heat addition would have been 2,440 GJ under the operations schedule followed that year. Thus, with the new lighting system, 770 GJ had to be replaced by burning gas at 75% efficiency. This would require 27,470 m^3 of gas, worth about $3,300, to make up the difference. The actual annual savings then, for the new lighting system, would be about $4,600, the difference between the electrical cost avoidance and the gas cost incurrence.

If re-lamping is considered to be a necessary maintenance item, the pay-back of going to a more efficient system is about 0.8 years. This is based on the incremental cost of the more efficient system over a relamping to original specification. If relamping is considered to be necessary only for the energy savings, setting potential savings in energy against the entire capital cost of the project, then the payback is still only 4.0 years.

9.3 Overall Review

It is clear that this project has demonstrable technical value; the light levels and, possibly, productivity have increased over the previous condition. In addition, the project can certainly be justified on the grounds of energy savings. The payback period is reasonable regardless of whether the project is viewed as a maintenance project or as an energy conservation opportunity.

In summarizing this case study, we should look at the large picture. In general, there is no evidence that what were considered to be the major projects for conserving gas, the energy management system and the ceiling fans, have performed to expectations. Why might that be?

The heat load may reasonably be broken down into three components: the structural load (convection and radiation from building surfaces to atmosphere), the regular infiltration load (cold air infiltration at joints, door edges and windows) and the production-dependent infiltration which is primarily from cold air entering through open doors. Normally, we would consider the structural load to be the most substantial of these, with the regular infiltration being a distant second. Infiltration from open doors would be considered fairly small and variable because doors are generally assumed to be open only a small portion of the time. What if those assumptions were incorrect? What if the doors were actually open much more than was supposed? The infiltration through the doors could then be much greater than was assumed and the resulting heat load a much more substantial proportion of the total heat load. Of course, this would mean that the structural load would be a smaller proportion of the total. The saving expected as a result of installing ceiling fans would therefore be less significant, as the ceiling fans act primarily to reduce the structural load.

Moreover, the door infiltration occurs entirely during the day, when the set-back system has the heat equipment set on high. Again, if this door infiltration turned out to be fairly substantial, then the major portion of all the heat required could be used during the day, regardless of the set-back of temperature at night. If these doors are a major factor, the significance of the contribution that the ceiling fans and the energy management system can make is greatly reduced.

In fact, there is some evidence that this could well be the case. Recently, staff at Livingston Export Packing have developed a timer to be placed on doors to measure elapsed "door-open" time. The results of just a few tests have been surprising. It had been thought that a particular door might be open, say, 10% of production hours. The staff have found that the number of open hours is very much greater, ranging from 40% to 60% of production hours. If even a few of the doors in the warehouse under consideration show a similar pattern, this represents a very significant breach of the building envelope. It may well be the cause of the poor showing of these two energy conservation measures.

Another point should be made. Many manufacturers of energy conservation equipment rely on analytic tools which are empirical models of building performance developed for use in the design of heating and air-conditioning systems. These models usually incorporate conservative design parameters because, while energy was cheap, it was more important that a system operate reliably than efficiently. These models tend to rely on averaged input conditions which may not be particularly appropriate to the case where energy conservation measures are to be evaluated. Moreover, the conservatism inherent in these techniques tends to overstate savings as well.

In summary, the energy conservation measures taken and their effectiveness are as follows:

. Installation Of An Energy Management System For Heating Equipment

There is little evidence that this measure has been effective. We expect that the failure of the energy management system to live up to expectations is a result of a high door infiltration load during the day. This would concentrate much of the normal heating load to the day and reduce the significance of the night set-back system.

- Installation of Ceiling Fans For Better Heat Distribution

There is little evidence that this measure has been effective, but this could also be due to a high door infiltration load. If the door infiltration load is higher relative to the whole, the structural load is relatively smaller. Thus, the ceiling fans would have a less significant impact on the overall consumption because they operate primarily on the structural load.

- Installation of An Air-Curtain On A Large Shipping Door

Direct evidence was found that this measure was effective in reducing open door infiltration, but it is hard to tell how the heating savings would stack up against the electrical costs incurred to operate the air-curtain. Some measure is certainly indicated to reduce open door infiltration, but perhaps a passive system should be considered.

- Installation of Hug-Strips On All Shipping Doors

It is too early to tell the effectiveness of this measure, but it should reduce the normal infiltration load substantially, especially at night.

- Relamping The Entire Building With More Efficient Lamps

Savings can be measured directly from the ratings of the previous equipment to the new and the connected loads. There is no doubt that an excellent return is obtained.

Finally, we wish to emphasize our view that the door infiltration probably has a major impact on the energy consumption of this building, and probably many others like it. Reducing this infiltration would enhance the relative savings to be found in the use of set-back, ceiling fans and hug-strips.

It is therefore essential that this factor be given first consideration in evaluating any type of energy conservation opportunity to be applied to this category of building.

After reviewing our results and the preceding text of this report, Mr. Robert Lehman, plant engineer at Livingston Export Packing, had this to say:

"The impact of door infiltration appears to be significant. Data which we are now accumulating by means of the device which we built to monitor door openings, and total time open, bear this out. We have monitored three of the high traffic doors for one week each at this plant. The following information has been revealed:

Door #	Direction Facing	Size WxH	Monitored Period	Working Hours	Time Open	Times Opened	Avg. (Daytime) Temp. ^{o}F
#17	North	14'x16'	3/9-3/16	40	16 hrs.	330	$35^{o}F$
# 7	East	16'x16'	3/16-3/23	39	16.5 hrs.	406	$36^{o}F$
# 6	East	14'x16'	3/23-3/30	40	26.4 hrs.	276	$41^{o}F$

This serves to prove that some action should be taken to reduce heat losses at the doors during normal working hours. All other conservation efforts are negated if we don't.

The fact that there is no evidence to prove the effectiveness of the measures we have taken points out the need for in-plant, task-oriented metering of energy usage. Calculations of potential savings presented by manufacturers and vendors of energy conservation equipment are often self-serving and misleading. This is either because of insufficient data, or misuse of it due to ignorance or flim flammery.

We had hoped that the projects which we initiated were somewhat synergistic; i.e., reduced power usage from unit heater fans and the more efficient

lighting system would compensate for the power used by the ceiling fans. Reduced heat output from the new lighting system is compensated by ceiling fans bringing the excess heat down where it is needed rather than lost through the roof.

More studies of the type which Moffat Engineering has conducted here are required, but coupled with that, greater use of in-plant metering of specific tasks and functions is imperative.

I hope some useful information can be gleaned from this particular study."

APPENDIX 1

Energy Audit Tabulations

Gross Natural Gas Energy Breakdowns

August 1977- December 1981

MONTH	MONTHLY HEAT GAIN FROM ELECT EQUIPMENT [GJ]	ANNUAL USEFUL ELECTRICAL INPUT [GJ]	ANNUAL GAS EQUIVALENT OF ELECTRIC INPUT @75% [cubic m]
AUG/77	447		
SEP/77	465		
OCT/77	417		
NOV/77	467		
DEC/77	469		
JAN/78	402		
FEB/78	442		
MAR/78	339		
APR/78	400		
MAY/78	400		
JUN/78	533		
JUL/78	722	2936	105050
AUG/78	566		
SEP/78	547		
OCT/78	356		
NOV/78	474		
DEC/78	461		
JAN/79	605		
FEB/79	672		
MAR/79	619		
APR/79	393		
MAY/79	375		
JUN/79	393		
JUL/79	375	3580	128092
AUG/79	382		
SEP/79	378		
OCT/79	335		
NOV/79	383		
DEC/79	347		
JAN/80	370		
FEB/80	460		
MAR/80	547		
APR/80	549		
MAY/80	546		
JUN/80	619		
JUL/80	585	2991	107018
AUG/80	1013		
SEP/80	278		
OCT/80	447		
NOV/80	519		
DEC/80	366		
JAN/81	398		
FEB/81	432		
MAR/81	353		
APR/81	444		
MAY/81	368		
JUN/81	375		
JUL/81	390	2959	105873
AUG/81	343		
SEP/81	408		
OCT/81	381		
NOV/81	372		
DEC/81	372		

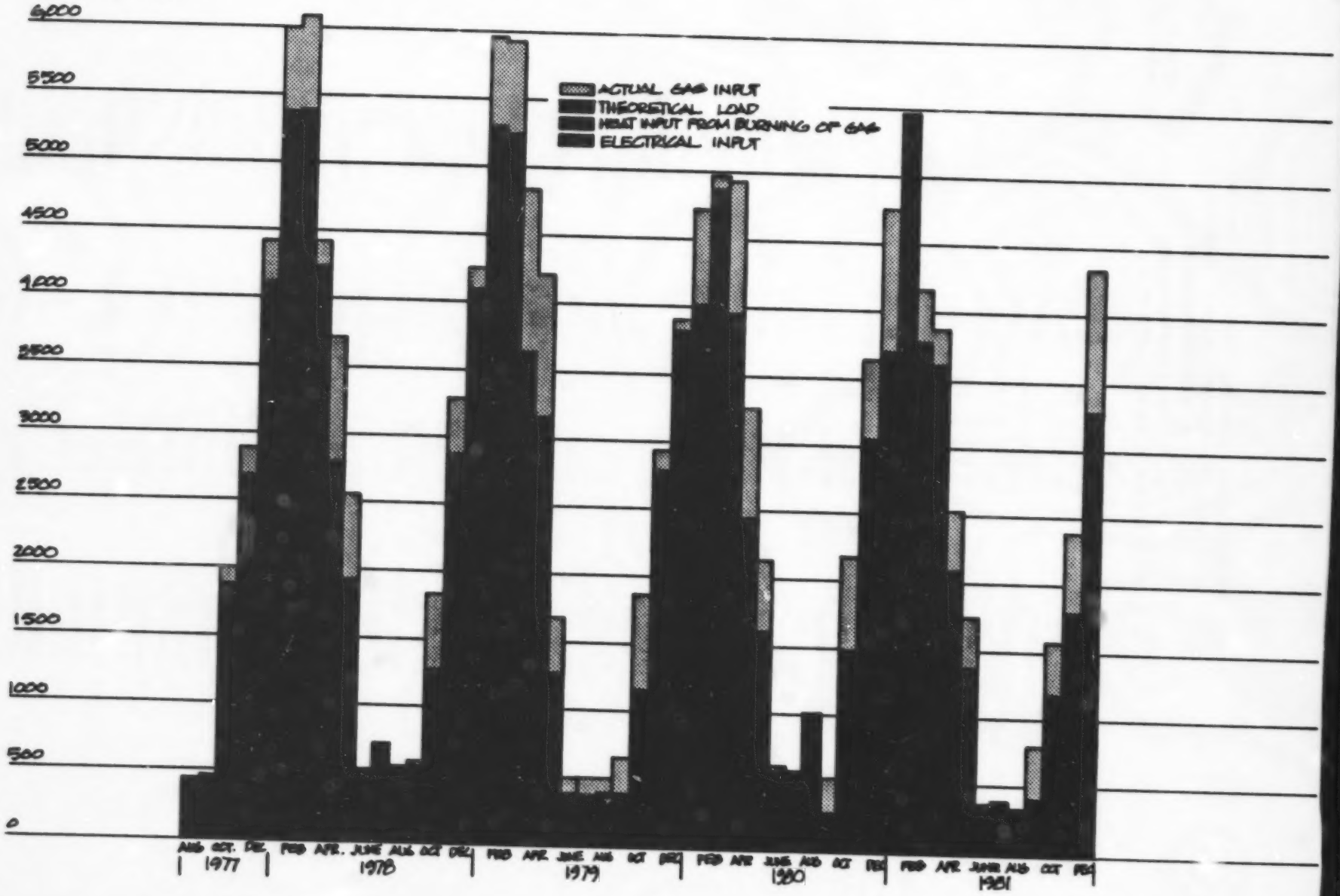
MONTH	MONTHLY DEGREE-DAYS FROM 18.3C	STRUCTURAL LOAD CO-EFF [MJ/d/C]	MONTHLY HEAT LOST THROUGH STRUCTURE [GJ]
AUG/77	35	5991	210
SEP/77	69	5991	413
OCT/77	284	5991	1701
NOV/77	405	5991	2426
DEC/77	668	5991	4002
JAN/78	814	5991	4877
FEB/78	816	5991	4889
MAR/78	670	5991	4014
APR/78	376	5991	2253
MAY/78	163	5991	977
JUN/78	49	5991	294
JUL/78	15	5991	90
AUG/78	4	5991	24
SEP/78	91	5991	545
OCT/78	279	5991	1671
NOV/78	433	5991	2594
DEC/78	620	5991	3714
JAN/79	803	5991	4811
FEB/79	794	5991	4757
MAR/79	483	5991	2894
APR/79	375	5991	2247
MAY/79	189	5991	1132
JUN/79	48	5991	288
JUL/79	12	5991	72
AUG/79	25	5991	150
SEP/79	99	5991	593
OCT/79	283	5991	1695
NOV/79	420	5991	2516
DEC/79	591	5991	3541
JAN/80	712	5991	4266
FEB/80	737	5991	4415
MAR/80	599	5991	3589
APR/80	338	5991	2025
MAY/80	135	5991	809
JUN/80	88	5991	527
JUL/80	4	5991	24
AUG/80	2	5991	12
SEP/80	85	5991	509
OCT/80	331	5991	1983
NOV/80	462	5991	2768
DEC/80	721	5991	4320
JAN/81	829	5991	4967
FEB/81	571	5991	3421
MAR/81	546	5991	3271
APR/81	317	5991	1899
MAY/81	187	5991	1120
JUN/81	25	5991	150
JUL/81	6	5991	36
AUG/81	12	5991	72
SEP/81	123	5991	737
OCT/81	NA	5991	NA
NOV/81	NA	5991	NA
DEC/81	NA	5991	NA

MONTH	MONTHLY DEGREE-DAYS FROM 18.3C	AVERAGE AIR CHANGE RATE [ACPH]	MONTHLY HEAT LOST THROUGH INFILTRATION [GJ]
AUG/77	35	.12	21
SEP/77	69	.12	42
OCT/77	284	.12	174
NOV/77	405	.12	248
DEC/77	668	.12	409
JAN/78	814	.12	499
FEB/78	816	.12	500
MAR/78	670	.12	411
APR/78	376	.12	230
MAY/78	163	.12	100
JUN/78	49	.12	30
JUL/78	15	.12	9
AUG/78	4	.12	2
SEP/78	91	.12	56
OCT/78	279	.12	171
NOV/78	433	.12	265
DEC/78	620	.12	380
JAN/79	803	.12	492
FEB/79	794	.12	487
MAR/79	483	.12	296
APR/79	375	.12	230
MAY/79	189	.12	116
JUN/79	48	.12	29
JUL/79	12	.12	7
AUG/79	25	.12	15
SEP/79	99	.12	61
OCT/79	283	.12	173
NOV/79	420	.12	257
DEC/79	591	.12	362
JAN/80	712	.12	436
FEB/80	737	.12	452
MAR/80	599	.12	367
APR/80	338	.12	207
MAY/80	135	.12	83
JUN/80	88	.12	54
JUL/80	4	.12	2
AUG/80	2	.12	1
SEP/80	85	.12	52
OCT/80	331	.12	203
NOV/80	462	.12	283
DEC/80	721	.12	442
JAN/81	829	.12	508
FEB/81	571	.12	350
MAR/81	546	.12	335
APR/81	317	.12	194
MAY/81	187	.12	115
JUN/81	25	.12	15
JUL/81	6	.12	4
AUG/81	12	.12	7
SEP/81	123	.12	75
OCT/81	NA	.12	NA
NOV/81	NA	.12	NA
DEC/81	NA	.12	NA

MONTH	REQUIRED HEAT INPUT TO MAINTAIN CONDITIONS [GJ]	THEORETICAL REQUIRED GAS AT 75% EFFICIENCY [cubic m]	ACTUAL GAS USED [cubic m]
AUG/77	0	0	0
SEP/77	0	0	34
OCT/77	1458	52184	53395
NOV/77	2208	78985	77516
DEC/77	3942	141056	111253
JAN/78	4973	177950	161364
FEB/78	4947	176992	163230
MAR/78	4086	146180	114183
APR/78	2083	74530	99527
MAY/78	676	24202	68836
JUN/78	0	0	6582
JUL/78	0	0	1056
AUG/78	0	0	0
SEP/78	54	1930	122
OCT/78	1486	53185	34173
NOV/78	2385	85351	88248
DEC/78	3633	130001	113806
JAN/79	4698	168088	160144
FEB/79	4571	163564	159213
MAR/79	2571	91977	129988
APR/79	2083	74544	113164
MAY/79	873	31240	45146
JUN/79	0	0	13535
JUL/79	0	0	6673
AUG/79	0	0	1127
SEP/79	276	9867	62
OCT/79	1534	54882	30915
NOV/79	2391	85535	78597
DEC/79	3556	127227	102632
JAN/80	4332	154995	107558
FEB/80	4407	157681	133453
MAR/80	3409	121962	132511
APR/80	1683	60220	87475
MAY/80	346	12362	57551
JUN/80	0	0	11604
JUL/80	0	0	0
AUG/80	0	0	0
SEP/80	283	10137	2234
OCT/80	1739	62216	39852
NOV/80	2532	90593	97958
DEC/80	4395	157264	99294
JAN/81	5077	181638	147283
FEB/81	3339	119460	112034
MAR/81	3253	116380	104475
APR/81	1649	59015	68363
MAY/81	867	31018	46927
JUN/81	0	0	2089
JUL/81	0	0	110
AUG/81	0	2	139
SEP/81	404	14465	3598
OCT/81	NA	NA	42349
NOV/81	NA	NA	63856
DEC/81	NA	NA	116705

MONTH	ANNUAL GAS USED [cubic m]	ANNUAL GAS CORRECTED FOR ELECT INPUT [cubic m]	ANNUAL DEG-DAYS	RATIO OF CORRECTED ANNUAL GAS TO ANNUAL DEG-DAYS
AUG/77				
SEP/77				
OCT/77				
NOV/77				
DEC/77				
JAN/78				
FEB/78				
MAR/78				
APR/78				
MAY/78				
JUN/78				
JUL/78	856976	962026	4364	220
AUG/78				
SEP/78				
OCT/78				
NOV/78				
DEC/78				
JAN/79				
FEB/79				
MAR/79				
APR/79				
MAY/79				
JUN/79				
JUL/79	864212	992304	4131	240
AUG/79				
SEP/79				
OCT/79				
NOV/79				
DEC/79				
JAN/80				
FEB/80				
MAR/80				
APR/80				
MAY/80				
JUN/80				
JUL/80	743485	850503	4031	211
AUG/80	3 YR AVG	934944	4175	224
SEP/80				
OCT/80				
NOV/80				
DEC/80				
JAN/81				
FEB/81				
MAR/81				
APR/81				
MAY/81				
JUN/81				
JUL/81	720619	826492	4082	202
AUG/81				
SEP/81				
OCT/81				
NOV/81				
DEC/81				

GROSS ENERGY USE BREAKDOWN : "NATURAL GAS"



Gross Electrical Energy Breakdowns

August 1977- December 1981

MONTH	FULL LOAD INDOOR LIGHTING WATTAGE [kW]	NIGHT INDOOR LIGHTING WATTAGE [kW]	WEEKLY FULL LOAD LIGHTING HOURS [h]	MONTHLY CONSUMPTION OF INDOOR LIGHTS [GJ]
AUG/77	284	35	55	305
SEP/77	284	35	55	305
OCT/77	284	35	55	305
NOV/77	284	35	55	305
DEC/77	284	35	55	305
JAN/78	284	35	55	305
FEB/78	284	35	55	305
MAR/78	284	35	55	305
APR/78	284	35	55	305
MAY/78	284	35	55	305
JUN/78	284	35	88	434
JUL/78	284	35	100	480
AUG/78	284	35	100	480
SEP/78	284	35	88	434
OCT/78	284	35	55	305
NOV/78	284	35	55	305
DEC/78	284	35	55	305
JAN/79	284	35	100	480
FEB/79	284	35	100	480
MAR/79	284	35	100	480
APR/79	284	35	55	305
MAY/79	284	35	55	305
JUN/79	284	35	55	305
JUL/79	284	35	55	305
AUG/79	284	35	55	305
SEP/79	284	35	55	305
OCT/79	284	35	55	305
NOV/79	284	35	55	305
DEC/79	284	35	55	305
JAN/80	284	35	55	305
FEB/80	284	35	55	305
MAR/80	284	35	100	480
APR/80	284	35	100	480
MAY/80	284	35	100	480
JUN/80	284	35	100	480
JUL/80	284	35	100	480
AUG/80	284	0	100	443
SEP/80	284	35	40	247
OCT/80	284	35	55	305
NOV/80	178	25	88	276
DEC/80	178	25	100	304
JAN/81	178	25	55	197
FEB/81	178	25	55	197
MAR/81	178	25	55	197
APR/81	178	25	55	197
MAY/81	178	25	55	197
JUN/81	178	25	55	197
JUL/81	178	25	55	197
AUG/81	178	25	55	197
SEP/81	178	25	55	197
OCT/81	178	25	55	197
NOV/81	178	25	55	197
DEC/81	178	25	55	197

MONTH	OUTDOOR LIGHTING WATTAGE [kW]	NIGHT OPERATING HOURS [h]	MONTHLY CONSUMPTION OF OUTDOOR LIGHTS [GJ]
AUG/77	20	0	0
SEP/77	20	0	0
OCT/77	20	0	1
NOV/77	20	1	2
DEC/77	20	2	3
JAN/78	20	1	2
FEB/78	20	0	1
MAR/78	20	0	0
APR/78	20	0	0
MAY/78	20	0	0
JUN/78	20	5	8
JUL/78	20	6	9
AUG/78	20	7	10
SEP/78	20	8	12
OCT/78	20	0	1
NOV/78	20	1	2
DEC/78	20	2	3
JAN/79	20	9	14
FEB/79	20	8	13
MAR/79	20	8	12
APR/79	20	0	0
MAY/79	20	0	0
JUN/79	20	0	0
JUL/79	20	0	0
AUG/79	20	0	0
SEP/79	20	0	0
OCT/79	20	0	1
NOV/79	20	1	2
DEC/79	20	2	3
JAN/80	20	1	2
FEB/80	20	0	1
MAR/80	20	8	12
APR/80	20	7	10
MAY/80	20	6	9
JUN/80	20	5	8
JUL/80	20	6	9
AUG/80	20	7	10
SEP/80	20	0	0
OCT/80	20	0	1
NOV/80	20	9	14
DEC/80	20	10	16
JAN/81	20	1	2
FEB/81	20	0	1
MAR/81	20	0	0
APR/81	20	0	0
MAY/81	20	0	0
JUN/81	20	0	0
JUL/81	20	0	0
AUG/81	20	0	0
SEP/81	20	0	0
OCT/81	20	0	1
NOV/81	20	1	2
DEC/81	20	2	3

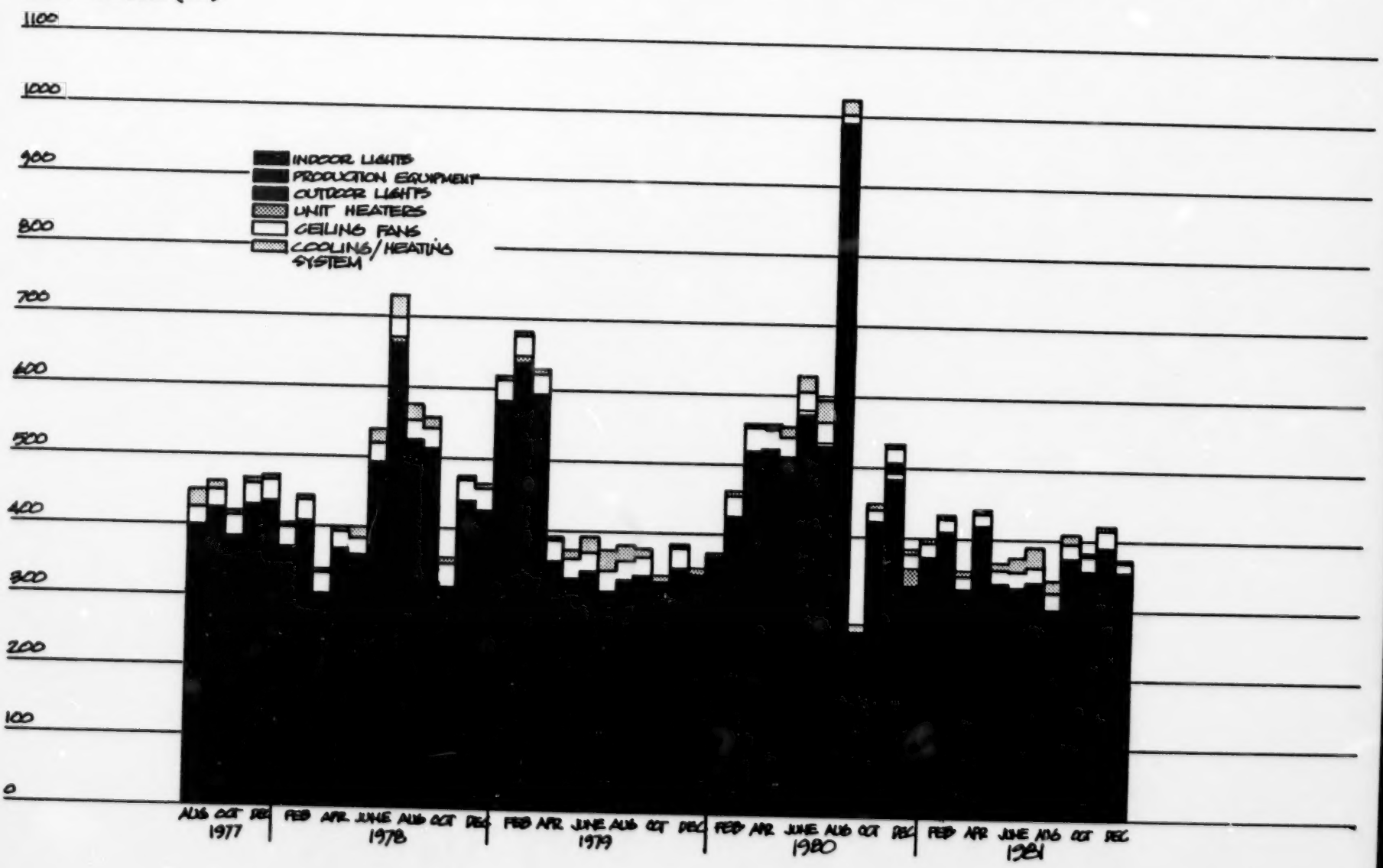
MONTH	AVG OFFICE CLG/HTG SYS WATTAGE [kW]	CLG/HTG SYS WEEKLY OPTG HOURS [h]	MONTHLY CONSUMPTION OF SYSTEM [GJ]
AUG/77	8	168	21
SEP/77	5	168	13
OCT/77	2	168	5
NOV/77	2	168	5
DEC/77	2	168	5
JAN/78	2	168	5
FEB/78	2	168	5
MAR/78	2	168	5
APR/78	2	168	5
MAY/78	5	168	13
JUN/78	8	168	21
JUL/78	12	168	31
AUG/78	8	168	21
SEP/78	5	168	13
OCT/78	2	168	5
NOV/78	2	168	5
DEC/78	2	168	5
JAN/79	2	168	5
FEB/79	2	168	5
MAR/79	2	168	5
APR/79	2	168	5
MAY/79	5	168	13
JUN/79	8	168	21
JUL/79	12	168	31
AUG/79	8	168	21
SEP/79	5	168	13
OCT/79	2	168	5
NOV/79	2	168	5
DEC/79	2	168	5
JAN/80	2	168	5
FEB/80	2	168	5
MAR/80	2	168	5
APR/80	2	168	5
MAY/80	5	168	13
JUN/80	8	168	21
JUL/80	12	168	31
AUG/80	8	168	21
SEP/80	5	168	13
OCT/80	2	168	5
NOV/80	2	168	5
DEC/80	2	168	5
JAN/81	2	168	5
FEB/81	2	168	5
MAR/81	2	168	5
APR/81	2	168	5
MAY/81	5	168	13
JUN/81	8	168	21
JUL/81	12	168	31
AUG/81	8	168	21
SEP/81	5	168	13
OCT/81	2	168	5
NOV/81	2	168	5
DEC/81	2	168	5

MONTH	CEILING FAN WATTAGE [kW]	WEEKLY CEILING FAN OPTG HOURS [h]	MONTHLY CONSUMPTION OF CEILING FANS [GJ]
AUG/77	0	0	0
SEP/77	0	0	0
OCT/77	0	0	0
NOV/77	0	0	0
DEC/77	0	0	0
JAN/78	0	0	0
FEB/78	0	0	0
MAR/78	0	0	0
APR/78	0	0	0
MAY/78	0	0	0
JUN/78	0	0	0
JUL/78	0	0	0
AUG/78	0	0	0
SEP/78	0	0	0
OCT/78	0	0	0
NOV/78	0	0	0
DEC/78	0	0	0
JAN/79	0	0	0
FEB/79	0	0	0
MAR/79	0	0	0
APR/79	0	0	0
MAY/79	0	0	0
JUN/79	0	0	0
JUL/79	0	0	0
AUG/79	0	0	0
SEP/79	0	0	0
OCT/79	0	0	0
NOV/79	0	0	0
DEC/79	0	0	0
JAN/80	0	0	0
FEB/80	0	0	0
MAR/80	0	0	0
APR/80	0	0	0
MAY/80	0	0	0
JUN/80	0	0	0
JUL/80	0	0	0
AUG/80	0	0	0
SEP/80	0	0	0
OCT/80	7	168	18
NOV/80	7	168	18
DEC/80	7	168	18
JAN/81	7	168	18
FEB/81	7	168	18
MAR/81	7	168	18
APR/81	7	168	18
MAY/81	7	168	18
JUN/81	7	168	18
JUL/81	7	168	18
AUG/81	7	168	18
SEP/81	7	168	18
OCT/81	7	168	18
NOV/81	7	168	18
DEC/81	7	168	18

MONTH	UNIT HEATER FAN WATTAGE [kW]	WEEKLY UNIT HEATER OPERATING HOURS [h]	MONTHLY CONSUMPTION OF UNIT HEATERS [GJ]
AUG/77	10	168	26
SEP/77	10	168	26
OCT/77	10	168	26
NOV/77	10	168	26
DEC/77	10	168	26
JAN/78	10	168	26
FEB/78	10	168	26
MAR/78	10	168	26
APR/78	10	168	26
MAY/78	10	168	26
JUN/78	10	168	26
JUL/78	10	168	26
AUG/78	10	168	26
SEP/78	10	168	26
OCT/78	10	168	26
NOV/78	10	168	26
DEC/78	10	168	26
JAN/79	10	168	26
FEB/79	10	168	26
MAR/79	10	168	26
APR/79	10	168	26
MAY/79	10	168	26
JUN/79	10	168	26
JUL/79	10	168	26
AUG/79	10	168	26
SEP/79	10	168	26
OCT/79	10	168	26
NOV/79	10	168	26
DEC/79	10	168	26
JAN/80	10	168	26
FEB/80	10	168	26
MAR/80	10	168	26
APR/80	10	168	26
MAY/80	10	168	26
JUN/80	10	168	26
JUL/80	10	168	26
AUG/80	10	168	26
SEP/80	10	0	0
OCT/80	10	0	0
NOV/80	10	168	26
DEC/80	10	168	26
JAN/81	10	168	26
FEB/81	10	168	26
MAR/81	10	168	26
APR/81	10	168	26
MAY/81	10	168	26
JUN/81	10	0	0
JUL/81	10	0	0
AUG/81	10	0	0
SEP/81	10	0	0
OCT/81	10	0	0
NOV/81	10	168	26
DEC/81	10	168	26
		168	26

MONTH	MONTHLY CONSUMPTION OF PRODUC EQUIPMENT [GJ]	TOTAL MONTHLY CONSUMPTION [GJ]
AUG/77	94	446
SEP/77	120	464
OCT/77	80	418
NOV/77	129	468
DEC/77	132	472
JAN/78	65	403
FEB/78	105	443
MAR/78	2	338
APR/78	63	400
MAY/78	55	400
JUN/78	52	540
JUL/78	184	731
AUG/78	38	576
SEP/78	73	558
OCT/78	19	356
NOV/78	137	475
DEC/78	124	464
JAN/79	93	619
FEB/79	159	684
MAR/79	107	630
APR/79	56	392
MAY/79	30	374
JUN/79	40	392
JUL/79	11	374
AUG/79	29	382
SEP/79	33	378
OCT/79	0	338
NOV/79	47	385
DEC/79	9	349
JAN/80	32	371
FEB/80	123	461
MAR/80	35	558
APR/80	36	558
MAY/80	26	554
JUN/80	91	626
JUL/80	47	594
AUG/80	548	1022
SEP/80	17	277
OCT/80	91	446
NOV/80	193	533
DEC/80	12	382
JAN/81	151	400
FEB/81	185	432
MAR/81	106	353
APR/81	196	443
MAY/81	139	367
JUN/81	138	374
JUL/81	142	389
AUG/81	106	342
SEP/81	179	407
OCT/81	135	382
NOV/81	173	421
DEC/81	125	374

GROSS ENERGY USE BREAKDOWN : "ELECTRICAL"



POOR

QUALITY

ORIGINAL